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Gaudette et al.

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(54) **AUTOMATIC CONFIGURATION OF A TEST ENVIRONMENT**

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
G06F 11/00 (2006.01)

(52) **U.S. Cl.**
USPC **714/33**; 714/25; 714/38.1; 702/123

(58) **Field of Classification Search**
USPC 714/25, 33, 38.1; 702/123
See application file for complete search history.

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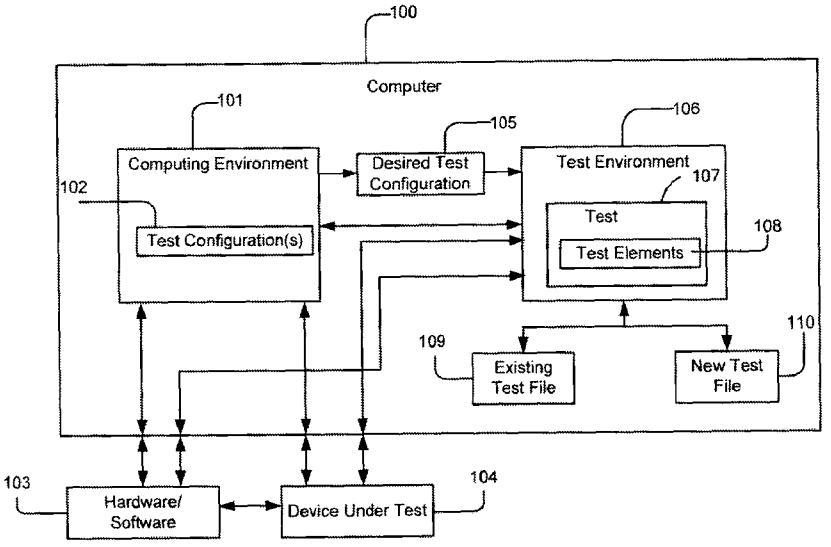
(57) **ABSTRACT**

Test configurations are generated based on information regarding hardware or software. A desired test configuration is selected. Test elements are automatically generated based on the desired test configuration, the test elements for testing at least one of the hardware or software. A plurality of test vectors is generated to test the hardware or software for the desired test configuration. The desired test configuration is converted to a script file. At least one of the hardware or software is automatically tested using the script file. Automatically testing the at least one of the hardware or the software includes using a first set of one or more test vectors from the plurality of test vectors to perform a plurality of test iterations of one or more of the actions of one or more generated test elements, and includes using at least a second set of one or more test vectors from the plurality of test vectors to determine the number of test iterations. A result of the testing is produced.

25 Claims, 14 Drawing Sheets



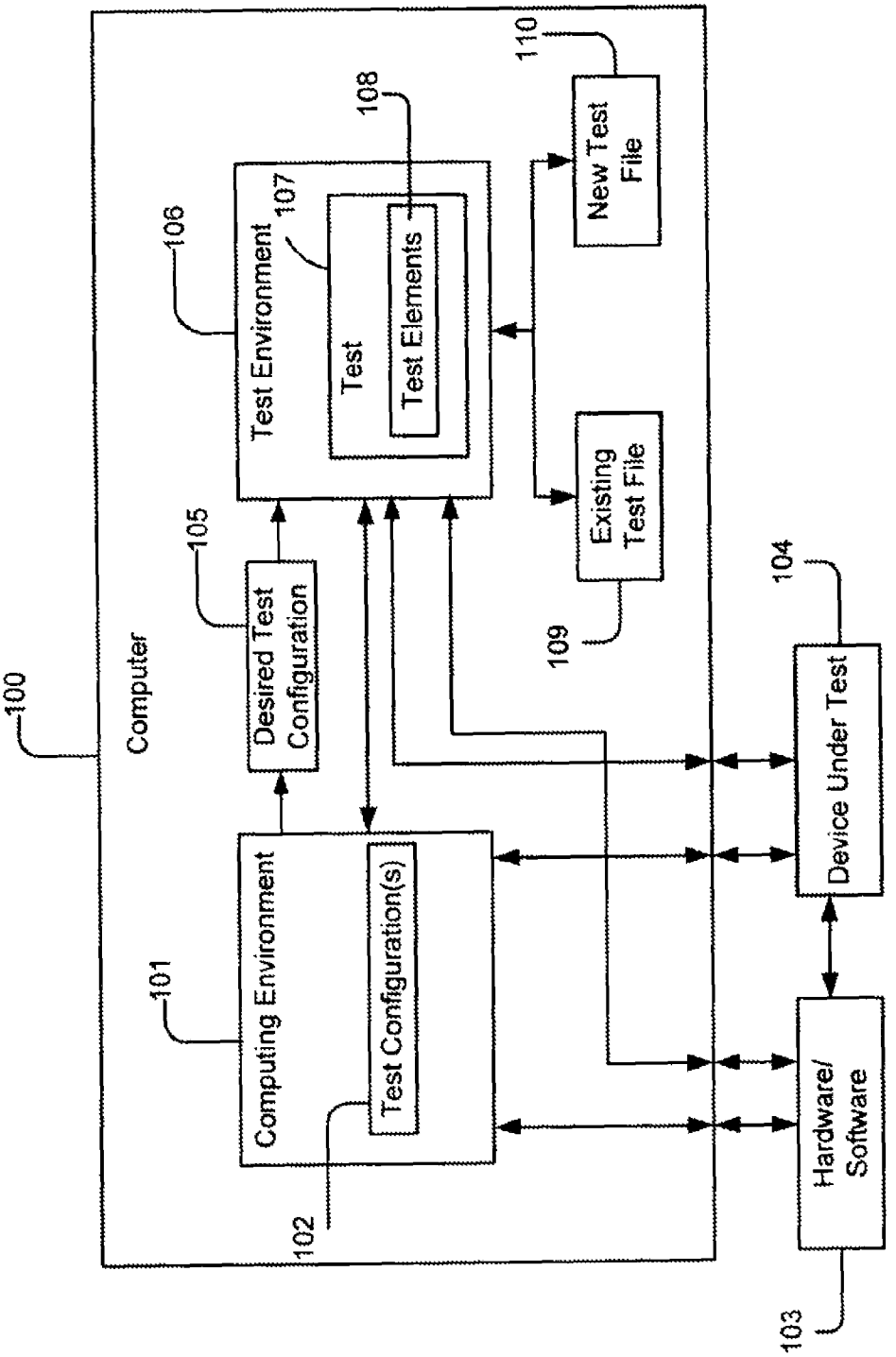

100
Computer
101
Computing Environment
Test Configuration(s)
102
103
Hardware/ Software
104
Device Under Test
105
Desired Test Configuration
106
Test Environment
107
Test
Test Elements
108
109
Existing Test File
110
New Test File

FIG. 1

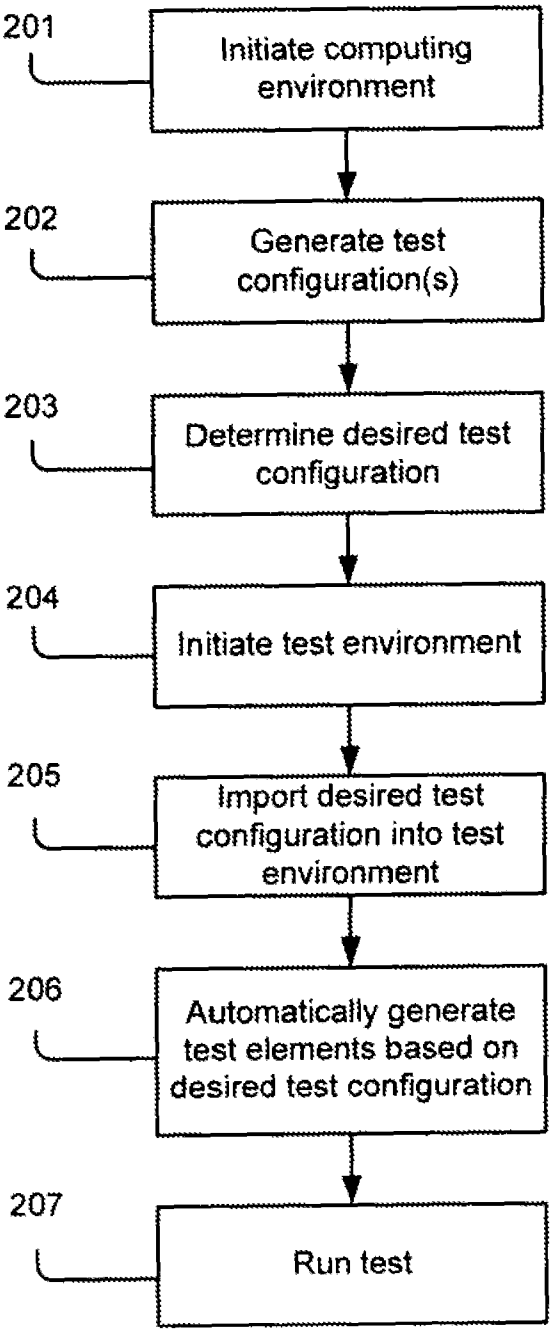

201
Initiate computing environment
202
Generate test configuration(s)
203
Determine desired test configuration
204
Initiate test environment
205
Import desired test configuration into test environment
206
Automatically generate test elements based on desired test configuration
207
Run test

FIG. 2

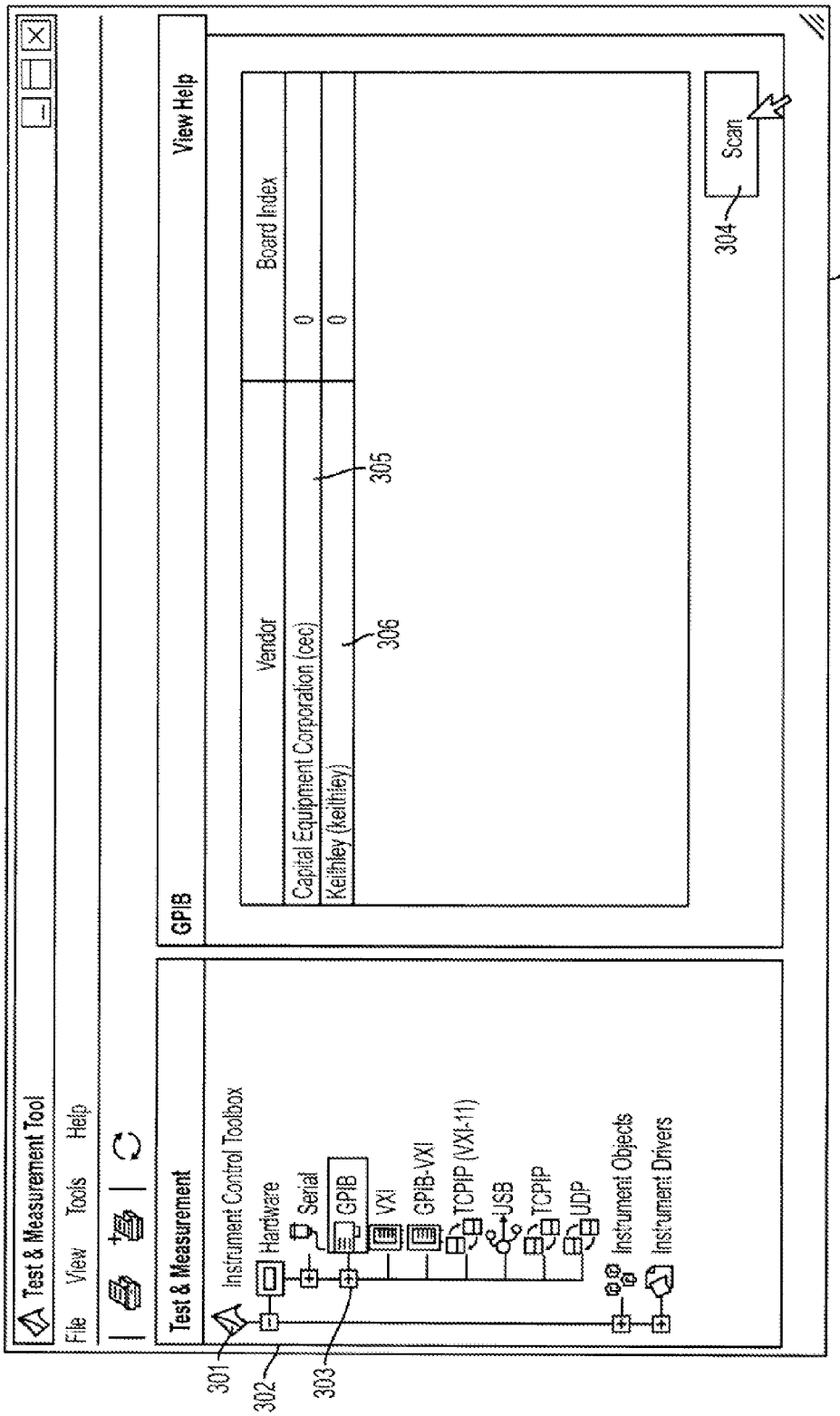

Test & Measurement Tool
File View Tools Help
Test & Measurement
Instrument Control Toolbox
Hardware
Serial
GPIB
VXI
GPIB-VXI
TCPIP (VXI-11)
USB
TCPIP
UDP
Instrument Objects
Instrument Drivers
GPIB
View Help
Vendor
Board Index
Capital Equipment Corporation (cec)
0
Keithley (keithley)
0
Scan
301
302
303
304
305
306
300

FIG. 3A

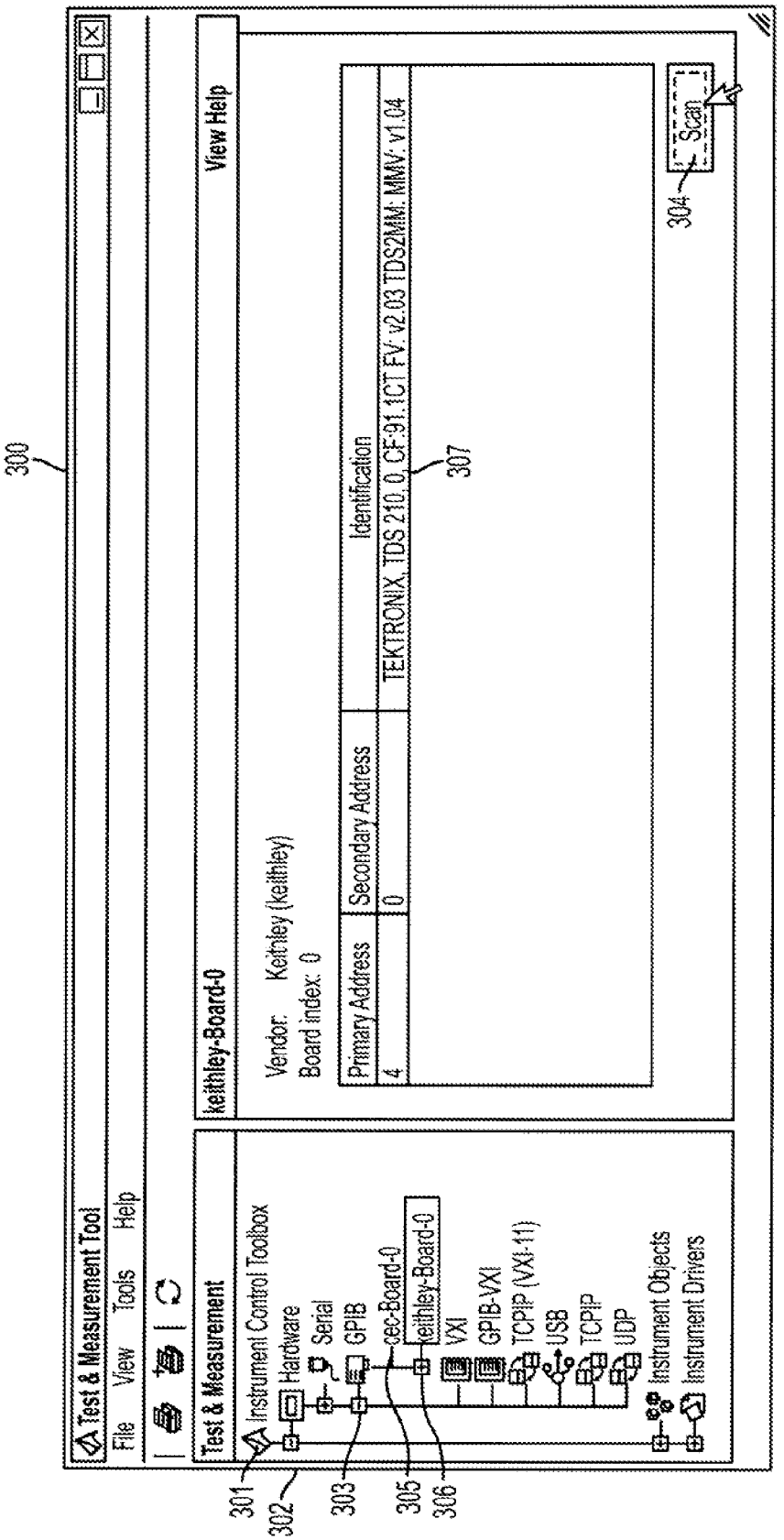

300
Test & Measurement Tool
File View Tools Help
Test & Measurement
Instrument Control Toolbox
Hardware
Serial
GPIB
cec-Board-0
keithley-Board-0
VXI
GPIB-VXI
TCPIP (VXI-11)
USB
TCPIP
UDP
Instrument Objects
Instrument Drivers
301
302
303
305
306
keithley-Board-0
View Help
Vendor: Keithley (keithley)
Board index: 0
Primary Address
Secondary Address
Identification
4
0
TEKTRONIX, TDS 210, 0, CF:91.1CT FV: v2.03 TDS2MM: MMV: v1.04
307
Scan
304

FIG. 3B

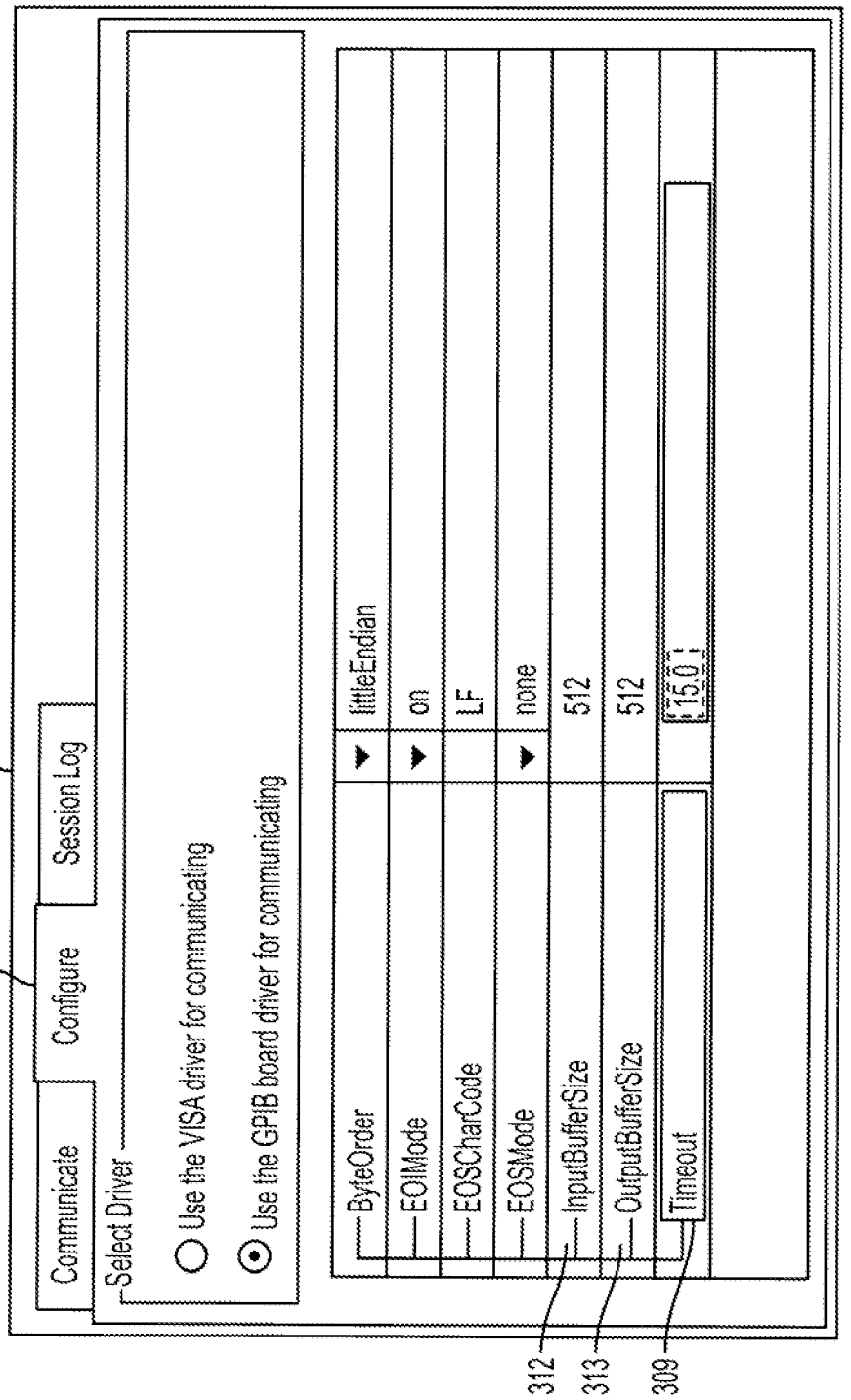

300
308
Communicate
Configure
Session Log
Select Driver
Use the VISA driver for communicating
Use the GPIB board driver for communicating
ByteOrder
littleEndian
EOIMode
on
EOSCharCode
LF
EOSMode
none
InputBufferSize
512
OutputBufferSize
512
Timeout
15.0
312
313
309

FIG. 3C

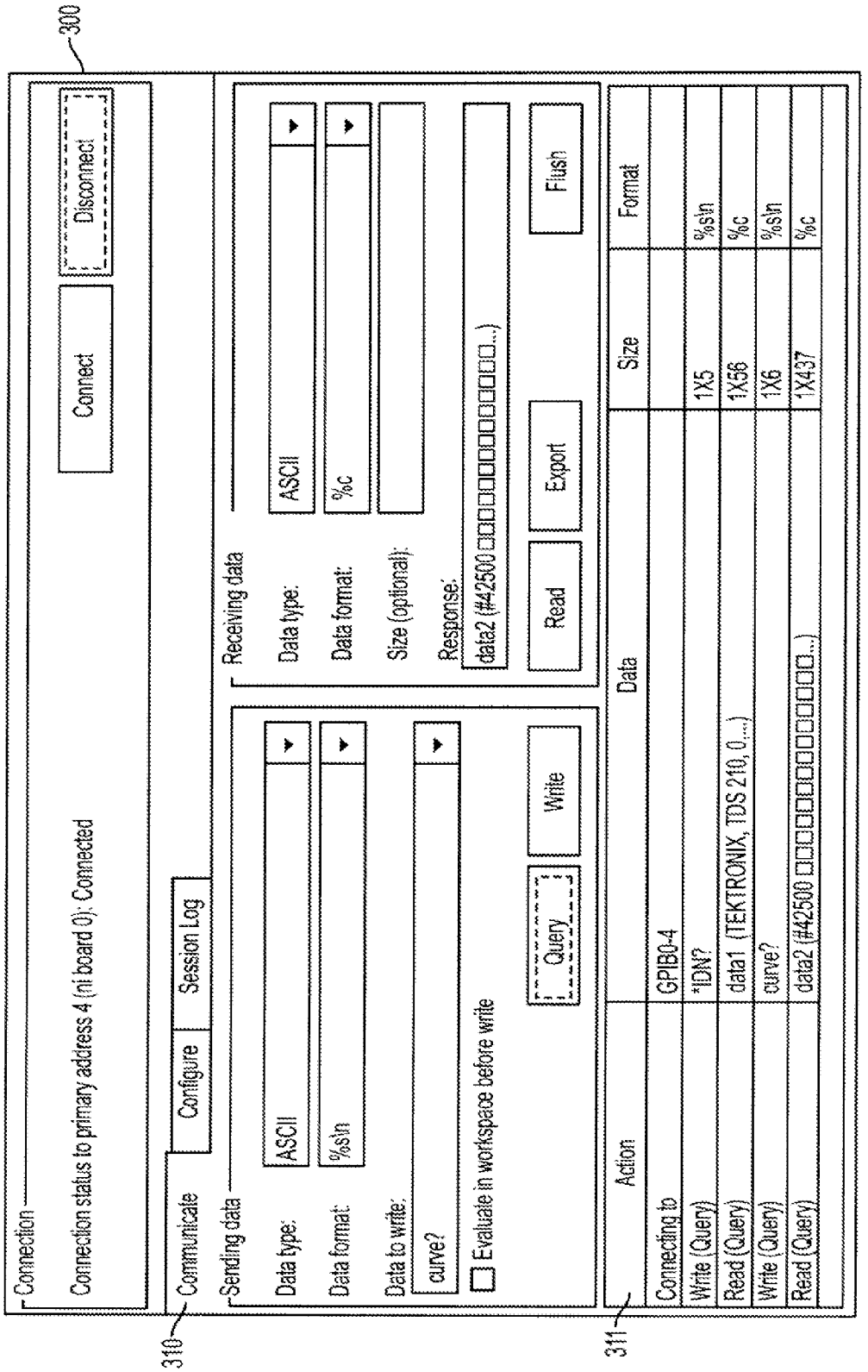

300
Connection
Connection status to primary address 4 (ni board 0): Connected
Connect
Disconnect
310
Communicate
Configure
Session Log
Sending data
Data type:
ASCII
Data format:
%s\n
Data to write:
curve?
Evaluate in workspace before write
Query
Write
Receiving data
Data type:
ASCII
Data format:
%c
Size (optional):
Response:
data2 (#42500...)
Read
Export
Flush
311
Action
Data
Size
Format
Connecting to
GPIB0-4
Write (Query)
*IDN?
1X5
%s\n
Read (Query)
data1 (TEKTRONIX, TDS 210, 0,...)
1X56
%c
Write (Query)
curve?
1X6
%s\n
Read (Query)
data2 (#42500...)
1X437
%c

FIG. 3D

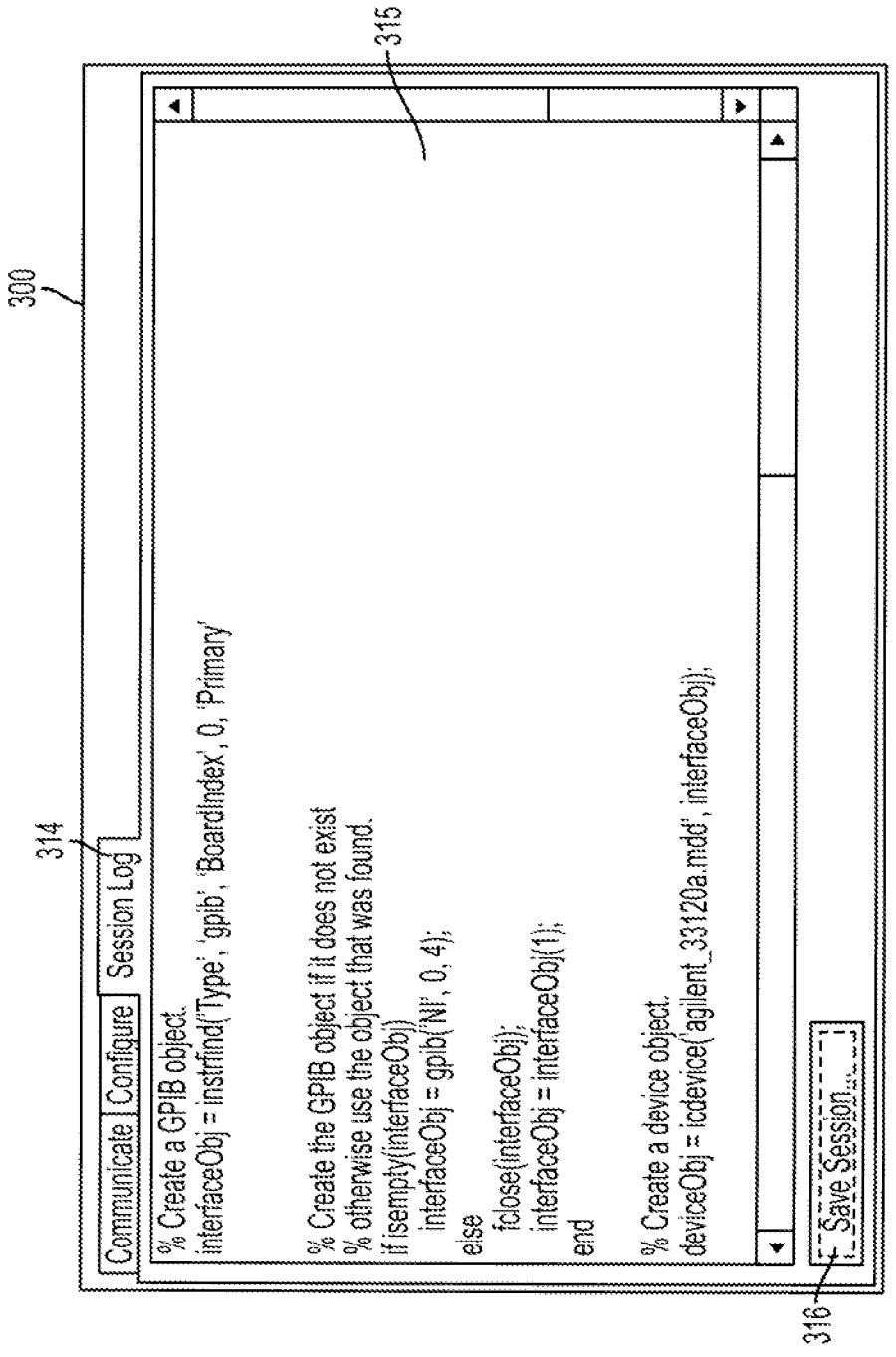

300
314
315
316
Communicate
Configure
Session Log
% Create a GPIB object.
interfaceObj = instrfind('Type', 'gpib', 'BoardIndex', 0, 'Primary'
% Create the GPIB object if it does not exist
% otherwise use the object that was found.
if isempty(interfaceObj)
interfaceObj = gpib('NI', 0, 4);
else
fclose(interfaceObj);
interfaceObj = interfaceObj(1);
end
% Create a device object.
deviceObj = icdevice('agilent_33120a.mdd', interfaceObj);
Save Session...

FIG. 3E

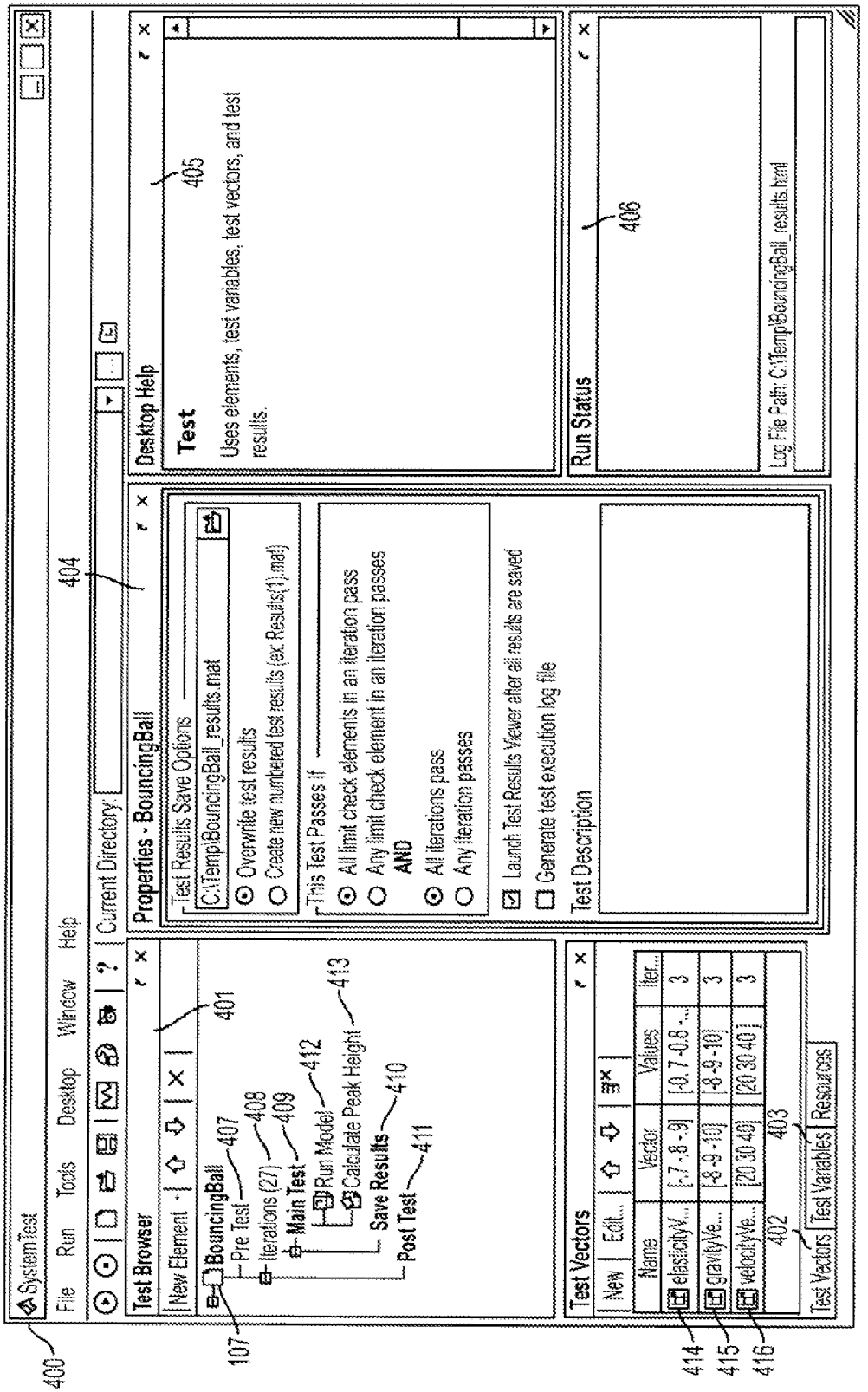

SystemTest
File Run Tools Desktop Window Help
Current Directory
Test Browser
New Element
BouncingBall
Pre Test
Iterations (27)
Main Test
Run Model
Calculate Peak Height
Save Results
Post Test
Properties - BouncingBall
Test Results Save Options
C:\Temp\BouncingBall_results.mat
Overwrite test results
Create new numbered test results (ex: Results(1).mat)
This Test Passes If
All limit check elements in an iteration pass
Any limit check element in an iteration passes
AND
All iterations pass
Any iteration passes
Launch Test Results Viewer after all results are saved
Generate test execution log file
Test Description
Desktop Help
Test
Uses elements, test variables, test vectors, and test results.
Run Status
Log File Path: C:\Temp\BouncingBall_results.html
Test Vectors
New
Edit...
Name
Vector
Values
iter...
elasticityV...
[-7 -8 -9]
[-0.7 -0.8 -...
3
gravityVe...
[-8 -9 -10]
[-8 -9 -10]
3
velocityVe...
[20 30 40]
[20 30 40]
3
Test Vectors
Test Variables
Resources
400
401
404
405
406
407
408
409
410
411
412
413
414
415
416
402
403
107

FIG. 4

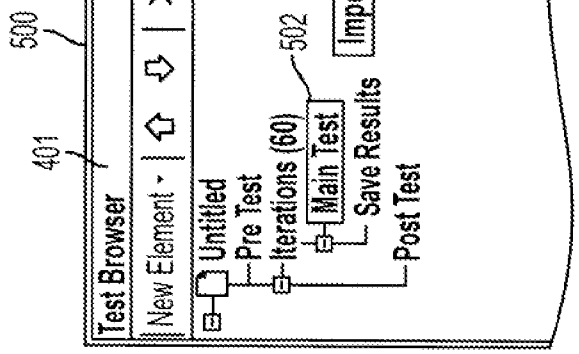

401
500
Test Browser
New Element
Untitled
Pre Test
Iterations (60)
Main Test
Save Results
Post Test
502
501
Import Test Configuration...

FIG. 5

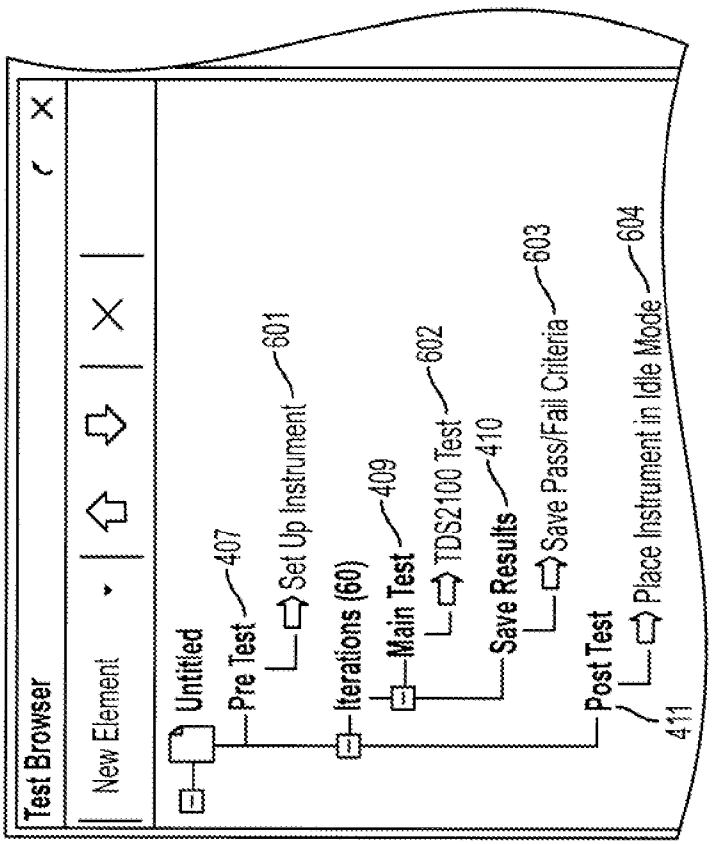

Test Browser
New Element
Untitled
Pre Test
Set Up Instrument
Iterations (60)
Main Test
TDS2100 Test
Save Results
Save Pass/Fail Criteria
Post Test
Place Instrument in Idle Mode
407
601
409
602
410
603
604
411

FIG. 6

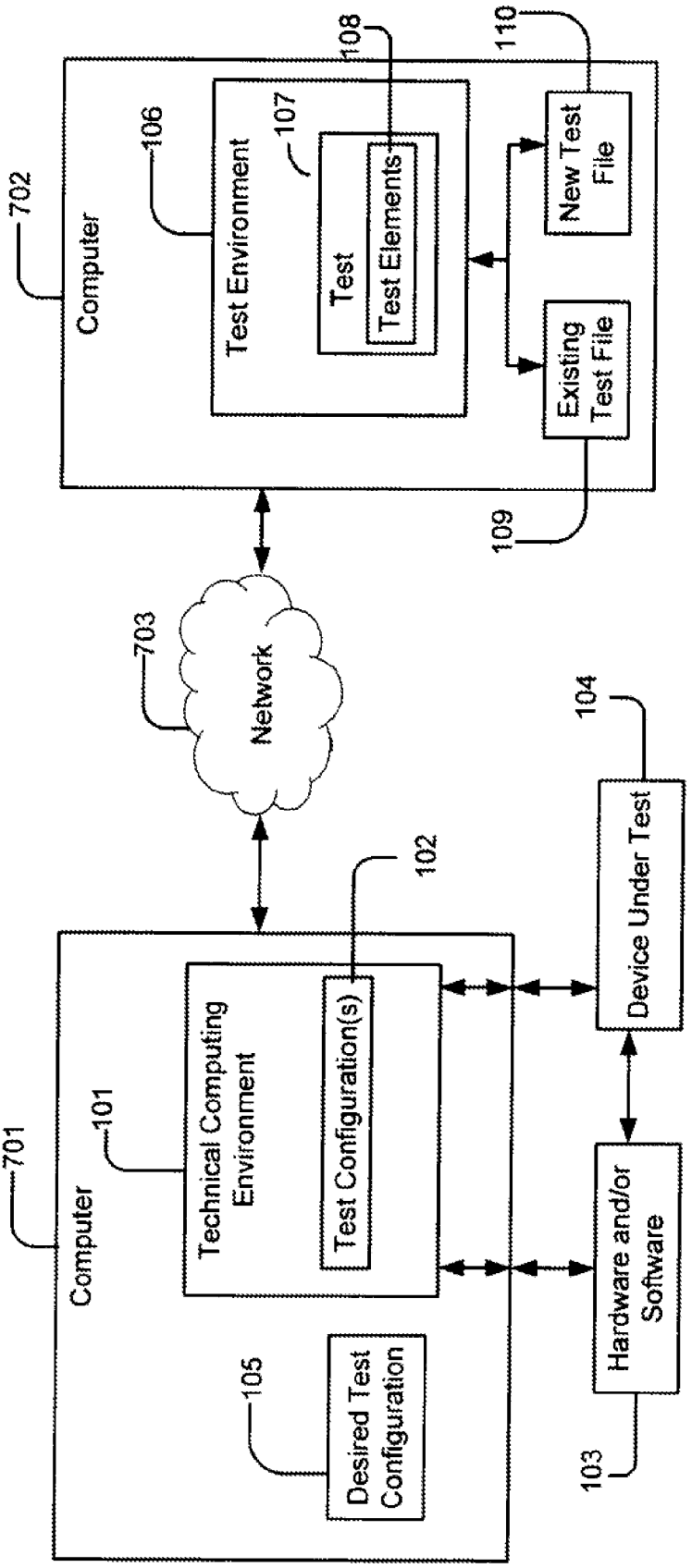

702
Computer
106
Test Environment
107
Test
Test Elements
108
110
New Test File
Existing Test File
109
703
Network
104
Device Under Test
102
701
Computer
101
Technical Computing Environment
Test Configuration(s)
105
Desired Test Configuration
Hardware and/or Software
103

FIG. 7

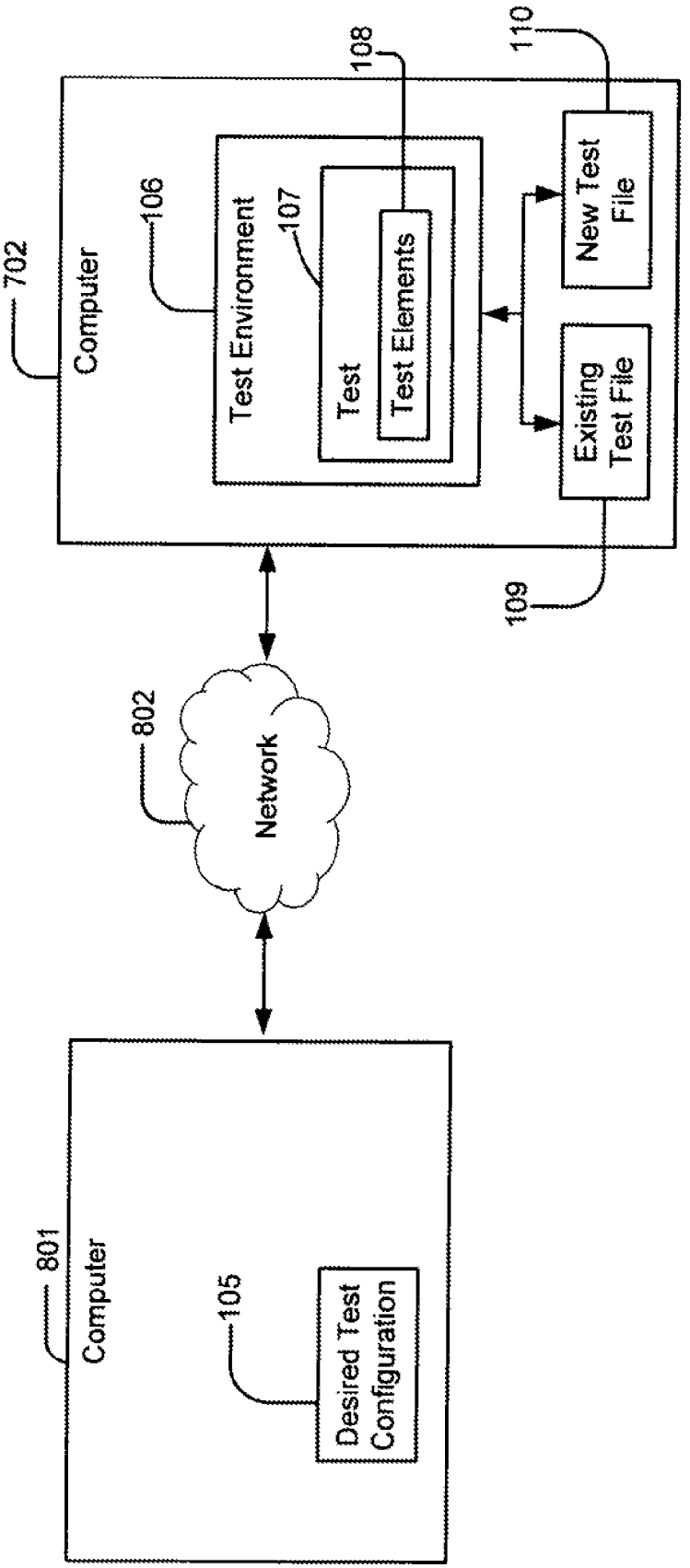

801
Computer
105
Desired Test Configuration
802
Network
702
Computer
106
Test Environment
107
Test
Test Elements
108
110
New Test File
Existing Test File
109

FIG. 8

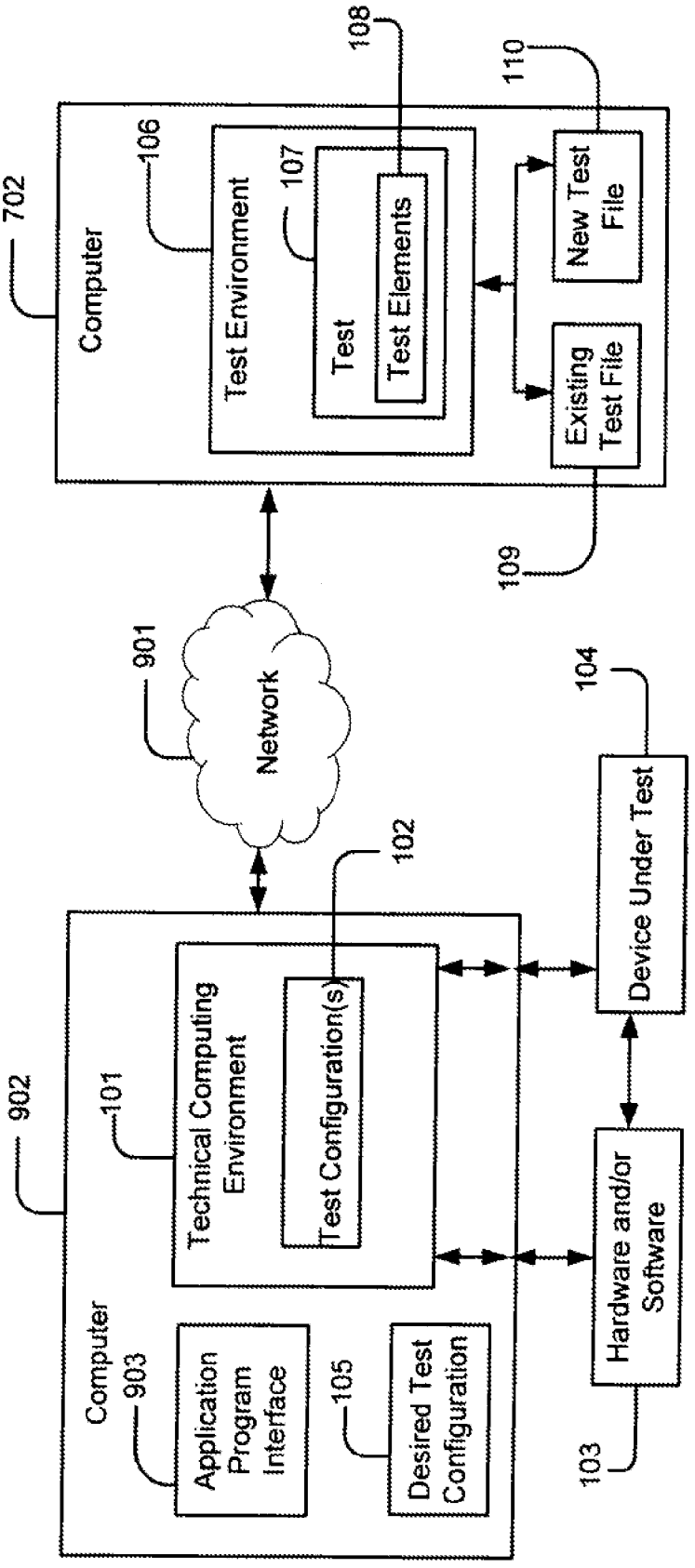

702
Computer
106
Test Environment
107
Test
Test Elements
108
110
New Test File
Existing Test File
109
901
Network
104
Device Under Test
102
902
101
Technical Computing Environment
Test Configuration(s)
Computer
903
Application Program Interface
105
Desired Test Configuration
Hardware and/or Software
103

FIG. 9

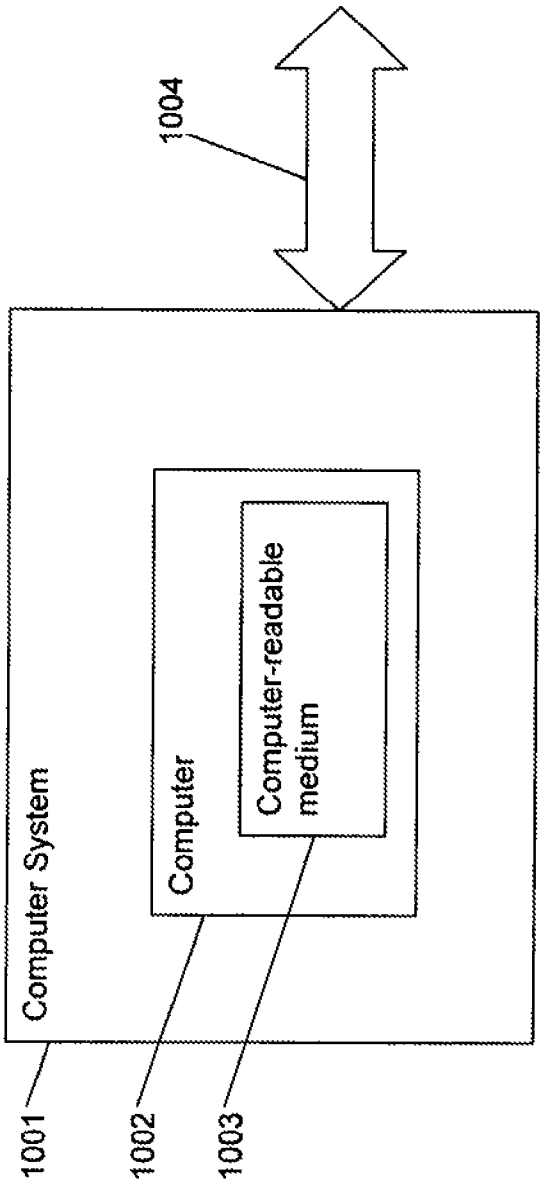

1004
Computer System
Computer
Computer-readable medium
1001
1002
1003

FIG. 10

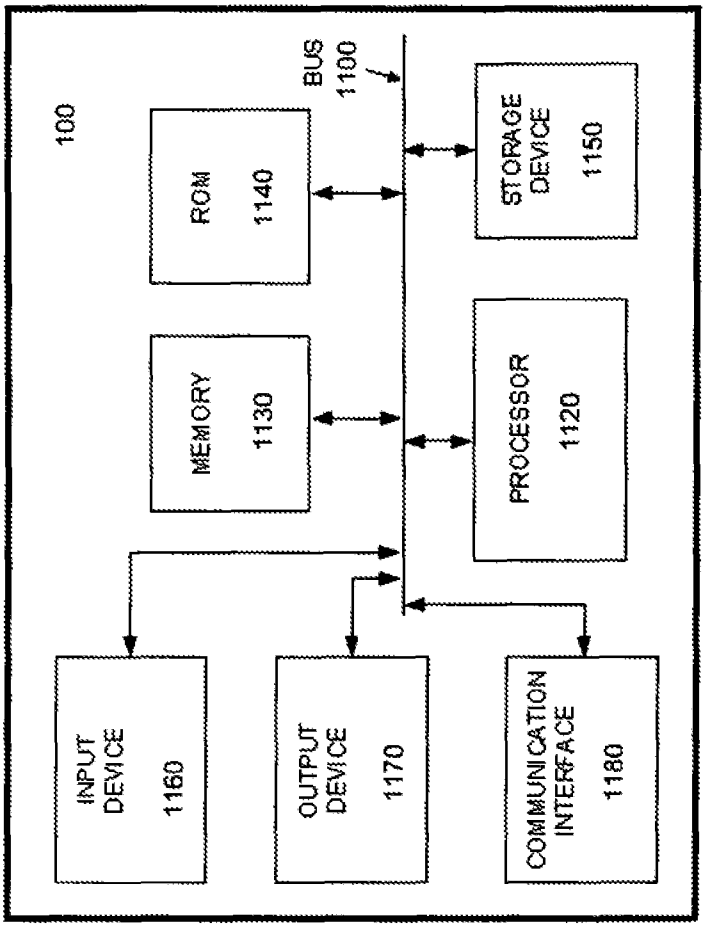

100
BUS
1100
ROM
1140
STORAGE DEVICE
1150
MEMORY
1130
PROCESSOR
1120
INPUT DEVICE
1160
OUTPUT DEVICE
1170
COMMUNICATION INTERFACE
1180

FIG. 11

AUTOMATIC CONFIGURATION OF A TEST ENVIRONMENT

RELATED APPLICATIONS

This patent application is a continuation of U.S. patent application Ser. No. 11/889,386, filed on Aug. 13, 2007, which is hereby incorporated herein by reference in its entirety.

BACKGROUND

Typically, a test engineer develops a test to test operation of a unit, system or software file under controlled conditions. The test engineer interested in developing test programs often needs to interface with an instrument to test the instrument itself, use the instrument to test a unit under test, or incorporate live measured data from the instrument into a test. Another example of a test is the verification and validation of a system modeled in software. In such a scenario, a system designer often models a physical system or component in software to explore design ideas and parameters. A test may be used to verify different design iterations meet specific design requirements that must be satisfied. To create such a test system, test engineers use different techniques. For example, a test engineer may interact with the instrument directly without using a user interface or without using an additional computer to interface with the instrument. As another example, a test engineer may interact with the instrument directly using a user interface or using an additional computer to interface with the instrument. Such an interaction, however, is manually intensive and requires significant amount of time for a test engineer to write a test program, with no technique to automate the process.

As a further example, a test engineer may use a computing environment to determine how to optimally configure the instrument for a test. This conventionally involves selecting an instrument, ensuring that the computing environment can communicate with the instrument, iterating through various test configurations (e.g., various communication command sequences between the computing environment and the instrument), and determining the desired test configuration to use for the test by verifying the results of the various test configurations, either through visual inspection or by analysis.

Once a desired test configuration has been determined, a test engineer may attempt to incorporate this set up into a test environment. However, this step is not always seamless due to disparate tools being used by the computing environment and the test environment and/or limitations of the computing environment and the test environment. As a result, the test engineer must manually recode or re-implement the desired test configuration in the test environment.

SUMMARY

In one exemplary embodiment, a test for testing at least one of hardware or software may be generated in a first environment. A desired test configuration may be selected based on information regarding respective hardware or software. Test elements may be automatically generated based on the desired test configuration, the test elements adapted to test at least one of the respective hardware or software. At least one of the hardware or software may be automatically tested using a subset of the test elements. A result of the test is produced.

In another exemplary embodiment, a system may generate a test, a computer-implemented test environment may select a desired test configuration based on information regarding at least one of hardware or software, generate automatically test elements based on the desired test configuration, the test elements adapted to test at least one of the hardware or software, automatically test at least one of the hardware or software using a subset of the test elements, and produce a result of the test.

Further features of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of the invention will be apparent from the following, more particular description of exemplary embodiments of the invention, as illustrated in the accompanying drawings wherein like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The left most digits in the corresponding reference number indicate the drawing in which an element first appears.

FIG. **1** illustrates an exemplary configuration for an exemplary embodiment of the invention.

FIG. **2** illustrates a flowchart for configuring a test in an exemplary embodiment of the invention.

FIGS. **3**A to **3**E illustrate an exemplary graphical user interface for generating an exemplary desired test configuration.

FIG. **4** illustrates an exemplary graphical user interface for an exemplary test environment.

FIG. **5** illustrates an exemplary graphical user interface for importing a desired test configuration into a test environment.

FIG. **6** illustrates an exemplary graphical user interface for a desired test configuration imported into a test environment.

FIG. **7** illustrates another exemplary configuration for an exemplary embodiment of the invention.

FIG. **8** illustrates yet another exemplary configuration for an exemplary embodiment of the invention.

FIG. **9** illustrates yet another exemplary configuration for an exemplary embodiment of the invention.

FIG. **10** depicts a computer system for use with the exemplary embodiments of the invention.

FIG. **11** depicts an exemplary architecture that may be used to implement the exemplary computer of FIG. **1**.

DEFINITIONS

In describing the invention, the following definitions are applicable throughout (including above).

A "computer" may refer to one or more apparatus and/or one or more systems that are capable of accepting a structured input, processing the structured input according to prescribed rules, and producing results of the processing as output. Examples of a computer may include: a computer; a stationary and/or portable computer; a computer having a single processor, multiple processors, or multi-core processors, which may operate in parallel and/or not in parallel; a general purpose computer; a supercomputer; a mainframe; a super mini-computer; a mini-computer; a workstation; a microcomputer; a server; a client; an interactive television; a web appliance; a telecommunications device with internet access; a hybrid combination of a computer and an interactive television; a portable computer; a tablet personal computer (PC); a personal digital assistant (PDA); a portable telephone; application-specific hardware to emulate a computer and/or software, such as, for example, a digital signal processor

(DSP), a field-programmable gate array (FPGA), an application specific integrated circuit (ASIC), an application specific instruction-set processor (ASIP), a chip, chips, a system on a chip, or a chip set; a data acquisition device; an optical computer; and an apparatus that may accept data, may process data in accordance with one or more stored software programs, may generate results, and typically may include input, output, storage, arithmetic, logic, and control units.

"Software" may refer to prescribed rules to operate a computer. Examples of software may include: code segments in one or more computer-readable languages; graphical and or/textual instructions; applets; pre-compiled code; interpreted code; compiled code; and computer programs.

A "computer-readable medium" may refer to any storage device used for storing data accessible by a computer. Examples of a computer-readable medium may include: a magnetic hard disk; a floppy disk; an optical disk, such as a CD-ROM and a DVD; a magnetic tape; a flash memory; a memory chip; and/or other types of media that can store machine-readable instructions thereon.

A "computer system" may refer to a system having one or more computers, where each computer may include a computer-readable medium embodying software to operate the computer or one or more of its components. Examples of a computer system may include: a distributed computer system for processing information via computer systems linked by a network; two or more computer systems connected together via a network for transmitting and/or receiving information between the computer systems; a computer system including two or more processors within a single computer; and one or more apparatuses and/or one or more systems that may accept data, may process data in accordance with one or more stored software programs, may generate results, and typically may include input, output, storage, arithmetic, logic, and control units.

A "network" may refer to a number of computers and associated devices that may be connected by communication facilities. A network may involve permanent connections such as cables or temporary connections such as those made through telephone or other communication links. A network may further include hard-wired connections (e.g., coaxial cable, twisted pair, optical fiber, waveguides, etc.) and/or wireless connections (e.g., radio frequency waveforms, free-space optical waveforms, acoustic waveforms, etc.). Examples of a network may include: an internet, such as the Internet; an intranet; a local area network (LAN); a wide area network (WAN); and a combination of networks, such as an internet and an intranet. Exemplary networks may operate with any of a number of protocols, such as Internet protocol (IP), asynchronous transfer mode (ATM), and/or synchronous optical network (SONET), user datagram protocol (UDP), IEEE 702.x, etc.

A "computing environment" may refer to an environment that allows users to create, analyze, simulate, or test models. A computing environment may be textual and/or graphical. Exemplary embodiments may exist as part of a textual technical computing environment such as MATLAB® by The MathWorks, Inc. of Natick, Mass., MATHEMATICA® by Wolfram Research, or COMSOL® Script by Comsol, Inc. The techniques described herein may be embodied in functional components, such as, for example, in a function, a model, a class, or other program element. Exemplary embodiments may alternatively exist as a part of a technical computing environment that has graphical models, such as SIMULINK® and STATEFLOW® by The MathWorks, Inc. of Natick Mass., or LABVIEW® by National Instruments Corporation. The techniques described herein may be embodied in functional components of such a computing environment, such as, for example, in a simulation block, or in simulation toolset.

DETAILED DESCRIPTION

Exemplary embodiments are discussed in detail below. While specific exemplary embodiments are discussed, it should be understood that this is done for illustration purposes only. In describing and illustrating the exemplary embodiments, specific terminology is employed for the sake of clarity. However, the invention is not intended to be limited to the specific terminology so selected. A person skilled in the relevant art will recognize that other components and configurations may be used without parting from the spirit and scope of the invention. It is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish a similar purpose. The examples and embodiments described herein are non-limiting examples.

A technical computing environment may be used to determine a desired test configuration for an instrument. A test environment (e.g., SystemTest by The Mathworks, Inc. of Natick, Mass.) uses the desired test configuration to automatically determine test elements for a test. The desired test configuration may be defined externally from the test environment. The test environment may be used for carrying out one or more tests on the instrument, device or system under test.

FIG. **1** depicts an exemplary configuration for an exemplary embodiment of the invention. FIG. **2** depicts a flowchart for the exemplary configuration for an exemplary embodiment of the invention.

In block **201**, a computing environment **101** may be initiated. Such computing environment **101** may be, for example, a technical computing environment. A technical computing environment may refer to a computing environment or system capable of processing or compiling code, for example, the code directed to technical computing applications. As an example, the computing environment **101** may be based on MATLAB® programming environment and the Test & Measurement Tool, provided with the Instrument Control Toolbox, by The MathWorks, Inc. of Natick, Mass.

In block **202**, one or more test configurations **102** may be generated using the computing environment **101**. A test configuration may be the information needed to setup inputs for a test, measure outputs of the test, and compare the measured outputs with known criteria. A test engineer may interact with the computing environment **101** via a graphical user interface to generate the test configurations **102**. The test configurations **102** may be generated for one or more instruments **103**. The test configurations **102** may, for example: interface with the instrument **103** to test the instrument **103**; use the instrument **103** to test a system or device under test or a simulation model of a system under test **104**; or incorporate live measured data from the instrument **103** into a test. The instrument may be hardware or software. Examples of hardware may include: a data acquisition device, an image acquisition device, a smart sensor, an automated test system (ATS), etc. The software may be software to read data from and/or write data to regarding a test. Examples of the software may include: custom code such as C, C++, or Java; a component object model (COM); one or more third-party application program interfaces (API); one or more machine-readable binary libraries; data processing software; signal processing software; curve fitting software; etc. As an example, the instrument **103** may be an oscilloscope, a function generator, a power supply, and/or any other equipment capable of per-

forming testing or being tested or generating data. The system under test **104** may be, for example, a unit under test such as a hardware device, a software algorithm, software files, a system model, software coverage testing, software testing with stubs, and the like. The simulation model of the system under test **104** may be textual and/or graphical. In one embodiment, one or more textual portions of the simulation model of the system under test **104** may be written in a matrix-based mathematical programming language. The matrix-based programming language may be a language including at least some operations adapted for processing arrays or matrices of data. For example, the matrix-based programming language may be MATLAB® programming language by The MathWorks, Inc. of Natick, Mass., or a language including a subset of instructions which is executable in the MATLAB® computing environment. Further, the test configurations **102** may be generated for one or more devices under test **104**. The test configuration **102** may interface directly with the device under test **104** without using the instrument **103**. In an alternative embodiment, the test configuration **102** may interface with a test environment **106**, which, in turn, may interface with the device under test **104**.

FIGS. **3**A to **3**E illustrate an exemplary graphical user interface or interfaces **300** for generating an exemplary desired test configuration as performed in blocks **202** and **203**. In this example, an exemplary desired test configuration entails communicating with a TDS 210 oscilloscope available from Tektronix of Beaverton, Oreg. via a general purpose interface bus (GPIB) interface such as, for example, a GPIB board by Capital Equipment Corp. of Norton, Mass. or a GPIB board by Keithley Instruments Inc, of Cleveland, Ohio. In the alternative embodiments, similar or different graphical and/or textual user interface may be used to allow a user to enter settings and/or test instructions for the instrument **103** and/or the device under test **104**.

In this example, the GPIB boards connected to the computer may be initially determined. As illustrated in FIG. **3**A, the test engineer may expand an instrument control toolbox **301**, expand a hardware **302**, and select a GPIB **303** from a pull-down list of available boards and/or interfaces. By clicking on a Scan button **304**, the computing environment **101** may scan the computer to determine what GPIB boards are installed. For example, a GPIB board **305** by Capital Equipment Corp. of Norton, Mass. and a GPIB board **306** by Keithley Instruments Inc. of Cleveland, Ohio may be installed on the computer of the shown embodiment.

Once the GPIB boards are determined, the instrument connected to a selected GPIB board may be determined. As illustrated in FIG. **3**B, the test engineer may expand the GPIB **303**, select the Keithley GPIB board **306**, and click the Scan button **304** to determine what instruments are connected to the selected Keithley GPIB board **306**. For this example, a TDS 210 oscilloscope **307** from Tektronix of Beaverton, Oreg. is connected to the Keithley GPIB board **306**.

Once the instrument is determined, the instrument connected to the computer may be configured. As illustrated in FIG. **3**C, the test engineer may select a Configure tab **308** and may adjust the settings of the TDS 210 oscilloscope. For this example, a value for a Timeout **309** has been set to 15 seconds, a value for an InputBufferSize **312** has been set to 512 bytes, and a value for an OutputBufferSize **313** has been set to 512 bytes.

Once the instrument is configured, a communication sequence for reading data from the instrument and writing data to the instrument may be generated. A communication sequence may be a code that performs the instrument selection, establishes a connection, and applies the desired configuration. At the request of the test engineer, a communication channel may be established with the instrument, and an interface object representing the communication channel to the instrument may be created. As illustrated in FIG. **3**D, the test engineer may select a Communicate tab **310** and provide instructions **311** to read from and write to the TDS **210** oscilloscope. In addition, data acquired from the instrument may be exported as, for example, a variable in a workspace, an array in a workspace, a plot in a separate window, an argument for use in an instrument control command, or a file for storage.

A test engineer may generate various test configurations for interfacing with the instrument **103** to determine the desired test configuration **105**. Continuing the above example, referring to FIG. **3**C, the test engineer may adjust settings of the TDS 210 oscilloscope to different values. For example, the Timeout value **309** may be set to 20 seconds, the InputBufferSize value **312** may be set to 1024 bytes, and the OutputBufferSize value **313** may be set to 1024 bytes. Further, referring to FIG. **3**D, additional or alternative commands for interacting with the instrument **103** may be executed. It is contemplated that the test instrument may communicate to more than one test environment.

In block **203**, a desired test configuration may be determined from the test configuration(s) determined in block **202**. The test engineer or the computing environment **101** may determine the desired test configuration **105**. If the computing environment **101** determines the desired test configuration **105**, the computing environment **101** may determine the desired test configuration **105** based on, for example, an optimization criterion. The desired test configuration may be a dynamically-created software program (e.g., a MATLAB® script code or MATLAB® program). The program may be saved to a file, which may be imported to the test environment **106** in block **205**, or it may be sent directly to the test environment **106**, without being saved to a file. As an alternative, the computing environment **101** may generate a machine readable software library that encapsulates the desired test configuration. Such library may be, for example, a compiled binary library or any other machine-readable component. The binary library may be imported and invoked by the test environment **106**. Continuing the above example, the desired test configuration for the TDS 210 oscilloscope may be converted to a script file and saved on the computer. A script file may be, for example, a file written in an array-based language and/or dynamically typed language. An array based language is a language having commands particularly adapted to operations on matrices or vectors. An example of an array based language may be a language at least a subset of commands of which are executable in the MATLAB® computing environment. In an alternative embodiment, a script file may be in any other programming language, such as, for example, C, C++, or other custom or industry-wide programming or scripting languages.

Referring to FIG. **3**E, the Session Log tab **314** may be selected, and a script file **315** may be automatically generated as the desired test configuration, and saved by a selection **316** by the test engineer.

In block **204**, the test environment **106** may be initiated. The test environment **106** may refer to a framework that integrates software, hardware, simulation, or other types of testing to develop a test, run the test, and save results from the test.

FIG. **4** illustrates an exemplary graphical user interface **400** for an exemplary test environment **106**. The test environment **106** may include a graphical user interface having a test

browser **401**, a test vectors pane **402**, a test variables pane **403**, a properties pane **404**, a help pane **405**, and a run status pane **406**.

In the test browser **401**, a test **107** may be generated. In the exemplary embodiment of FIG. **4**, the test **107** is labeled "BouncingBall." A test may include, for example, a pre test section **407**, an iterations part **408**, a main test section **409**, a save results part **410**, and a post test section **411**. The test browser **401** may be used to add or delete test elements **108** to the various sections of the test, as for example, the pre test section **407**, the main test section **409**, or the post test section **411**. The test elements **108** may determine actions for the test **107** to perform, such as, for example, to evaluate a script file written for a script language or simulate a model of a graphical or modeling environment. As an example, the test elements **108** may include: connecting to the instrument **103**; collecting data from the instrument **103**; comparing the collected data to known criteria; disconnecting from the instrument **103**. As a further example, the test elements **108** automatically generated from a desired test configuration may include: initiating test software; collecting data from the test software; comparing the collected data to known criteria; and closing the test software. Another example may be a single test element that is automatically generated to encapsulate the desired test configuration. In the exemplary embodiment of FIG. **4**, the main test section **409** includes a "Run Model" test element **412** and a "Calculate Peak Hight" test element **413**. It is contemplated that the test elements may be added to various sections of the test **107** by the test environment **106**.

The test vectors may specify the values that vary during each test iteration. The test vectors values may be specified by the user via the test vectors pane **402** and include arguments for algorithms or parameters and input signals for models. Test vectors may be displayed during test execution. A "test vector" may be a set of one or more values for one or more parameters in the model under test. Test vectors may be combined to generate a number of possible iterations through the test. Here, for example, three test vectors **414**, **415**, and **416** are displayed. In this example, each test vector has three sample points, and, thus, there are 27 iterations **408** through the test vectors, e.g., the total number of possible combinations is 3×3×3=27. In an alternative embodiment, not all possible combinations may be tested. For example, a user may specify which combinations of test vectors to test, which ones are related and may be executed as a group, or the test environment **106** or the computing environment **101** may determine a number and particularities of various test scenarios based on the test vectors. Some approaches to determining test iterations may include, for example: randomized sampling, sampling based on inter-relationships between the vectors, sampling based on previous test runs, etc. In yet another embodiment of the invention, different approaches may be used to determining the number of iterations through different test patterns, as deemed appropriate by one of skill in the art.

Test variables may be used to temporarily store data for use by the test elements **108** during test execution. The variables may be initialized in the pre-test section **408** or the main test section **409** via the test variables pane **403**. Alternatively, the test variables may be automatically initialized or defined as appropriate for the particular test environment.

The properties pane **404** may show the properties of the test or the test element that is being edited. The contents of the properties pane **404** may change when a test engineer selects a section or element in the test.

The help pane **405** may show help topics regarding the test element or aspect of the test that is currently selected.

The run status pane **406** may show a summary of the execution status of the test.

As mentioned above, in block **205**, the desired test configuration **105** may be imported into the test environment **106** for an associated test **107**. In one embodiment, the test engineer may identify the test **107** for which the desired test configuration **105** is to be imported. The test engineer may alternatively identify the desired test configuration **105**. The test environment **106** may then obtain the identified desired test configuration **105** for the test **107**.

Continuing the above example, the test engineer may identify the file including at least a part of the desired test configuration for the TDS 210 oscilloscope.

FIG. **5** illustrates an exemplary graphical user interface **500** for importing a desired test configuration into a test environment. As illustrated in FIG. **5**, the test engineer may invoke a right click menu option with a mouse that lists Import Test Configuration **501** and locate the file for the desired test configuration for the TDS 210 oscilloscope. As an alternative, the test engineer may click Main Test **502** in the test browser **401**, select Import Test Configuration **501** in the drop down menu, and locate the file for the desired test configuration for the TDS 210 oscilloscope. Other selection options may be made available to the test engineer.

In block **206**, one or more test elements **108** corresponding to the desired test configuration **105** may be automatically generated by the test environment **106**. The test environment **106** may automatically generate the two or more test elements **108** corresponding to the desired test configuration **105**. The test elements **108** may be created and configured without further input or intervention on the part of the test engineer. For example, MATLAB® test elements may be automatically generated for a MATLAB® desired test configuration. Continuing the above example, after the identification of the desired configuration file by the test engineer, the test environment **106** may automatically generate test elements **108** for the test **107** corresponding to the desired test configuration **105** for the TDS 210 oscilloscope. The test elements **108** may interface with one or more instruments **103** and/or with one or more devices under test **104** without using any instrument **103**.

As a part of generating the test elements **108**, the test environment **106** may insert the test elements **108** into the test **107**. The test **107** may be saved as an existing test file **109** or a new test file **110**.

FIG. **6** illustrates an exemplary graphical user interface for a desired test configuration imported into a test environment. Continuing the above example, as illustrated in FIG. **6**, the test environment **106** may automatically generate the following test elements: "Set Up Instrument" test element **601**; "TDS210 Test" test element **602**; "Save Pass/Fail Criteria" test element **603**; and "Place Instrument in Idle Mode" test element **604**. The "Set Up Instrument" test element **601** may be inserted into the pre test section **407**. The "TDS210 Test" test element **602** may be inserted into the main test section **409**; the "Save Pass/Fail Criteria" test element **603** may be inserted into the save results section **410**; and the "Place Instrument in Idle Mode" test element **604** may be inserted into the post test section **411**. Each test element may be identified with a particular icon and a reference. The particular icon may represent the type of test element (e.g., a MATLAB® environment test element).

In block **207**, after the test elements **108** have been created or inserted in the test **107**, the test environment **106** may run the test **107**. When the test element **108** corresponding to the desired test configuration **105** is run, the instrument **103** may be accessed according to the desired test configuration **105**.

The computing environment **101** and the test environment **106** may reside on the same computer **100**. As illustrated in FIG. **1**, one or more instruments **103** may be external to the computer **100** executing the computing environment **101**. As an alternative exemplary embodiment of the invention, one or more instruments **103** may be internal to the computer **100** executing the computing environment **101**. As illustrated in FIG. **1**, one or more devices under test **104** may be external to the computer **100** executing the computing environment **101**. As an alternative exemplary embodiment of the invention, one or more devices under test **104** may be internal to the computer **100** executing the computing environment **101**.

In the above exemplary embodiment of the invention, the interactions between a test engineer and the computing environment **101** and between a test engineer and the test environment **106** are illustrated using exemplary graphical user interfaces. As an alternative, command line interfaces may also be used.

In the above exemplary embodiment of the invention, the computing environment **101** may be initiated in block **201**, and then the test environment **106** may be initiated in block **204**. In an alternative exemplary embodiment, the test environment **106** may be initiated, and then the computing environment **101** may be initiated. For example, the test environment **106** may be initiated first, and a test may be generated. The computing environment **101** may be initiated, and a desired test configuration **105** may be generated and imported into the test environment **106**. Alternatively, the test environment **106** may initiate the computing environment **101** for defining a desired test configuration **105** to import.

In the above exemplary embodiment of the invention, the computing environment **101** and the test environment **106** may reside on the same computer **100**. In an alternative exemplary embodiment, as illustrated in FIG. **7**, the computing environment **101** and the test environment **106** may reside on different computers **701** and **702** connected via network **703**. In this exemplary embodiment, in block **205**, the desired test configuration **105** may be identified in the test environment **106** via a network address related to the computer **701** of the computing environment **101** (e.g., a file pathname on a local area network (LAN) for a computer-readable medium for the computer **701** of technical computing environment **101**).

In another alternative exemplary embodiment, as illustrated in FIG. **8**, the desired test configuration **105** may be previously generated and available for download from a computer **801** via a network **802**. The desired test configuration **105** may be stored on a computer-readable medium accessible via the network **802**. For this exemplary embodiment, in block **205**, the desired test configuration **105** may be identified in the test environment **106** via a network address related to the location of the desired test configuration **105** (e.g., a file pathname for a LAN-based computer-readable medium for the computer **801**, or a uniform resource locator (URL) for access over the Internet to the computer **801**).

In the above exemplary embodiment of the invention, the computing environment **101** may be used to generate the desired test configuration **105** during the design of the test in the test environment **106**. The computing environment **101** and the test environment **106** may reside on the same computer. In an alternative exemplary embodiment, as illustrated in FIG. **9**, the desired test configuration **105** may be generated in real time and transmitted or identified to the test environment **106** via a network **901**. For this exemplary embodiment, the desired test configuration **105** may be identified in the test environment **106** by a test engineer via a network address relative to the location of the computing environment **101** and the computer **902** on which computing environment **101** resides (e.g., a uniform resource locator (URL) for access over the Internet to the computer **902**). The network address may access a network-based computing environment **101**. Via an application program interface (API) **903** provided for the network-based computing environment **101**, a desired test configuration **105** may be generated in real time and imported into the test environment **106** via the network **901**. As an example, the API **903** may permit the test configuration **102**, defined in any third party computing environment **101**, to be compatible with the test environment **106**. By adhering to a defined API, the third-party may produce the test configuration **102** that may be invoked by the test environment **106**.

FIG. **10** depicts a computer system for use with exemplary embodiments of the present invention. The computer system **1001** may include one or more computers or computing units **1002** for implementing the invention. The computer **1002** may include a computer-readable medium **1003** embodying software for implementing the exemplary embodiments and/or software to operate the computer **1002** in accordance with the exemplary embodiments. As an option, the computer system **1001** may include a connection to a network **1004**. With this option, the computer **1002** may be able to send and receive information (e.g., software, data, documents) from other computer systems via the network **1004**. As discussed above, the computer **1002** may implement both the computing environment **101** and the test environment **106**. In another exemplary embodiment, the computer **1002** may implement the computing environment **101**, while another computer **1002**, or a computer system, similar to the computer system **1001**, may implement the test environment **106**.

The exemplary embodiments may be embodied in many different ways as a software component or a combination of software and/or hardware components. For example, it may be a stand-alone software package, or it may be a software package incorporated as a "tool" in a larger software product, such as, for example, a mathematical analysis product or a statistical analysis product. It may be downloadable from a network, for example, a website, as a stand-alone product or as an add-in package for installation in an existing software application. It may also be available as a client-server software application, or as a web-enabled software application. It may be embedded in custom or off-the shelf hardware, or may be implemented as a system on a chip or multiple chips.

FIG. **11** illustrates an exemplary architecture for implementing the computer **100** of FIG. **1**. It will be appreciated that other devices that can be used with the computer **100**, such as a client or a server, may be similarly configured. As illustrated in FIG. **11**, the computer **100** may include a bus **1110**, a processor **1120**, a memory **1130**, a read only memory (ROM) **1140**, a storage device **1150**, an input device **1160**, an output device **1170**, and a communication interface **1180**.

Bus **1110** may include one or more interconnects that permit communication among the components of computer **100**. Processor **1120** may include any type of processor, microprocessor, or processing logic that may interpret and execute instructions (e.g., a field programmable gate array (FPGA)). Processor **1120** may include a single device (e.g., a single core) and/or a group of devices (e.g., multi-core). Memory **1130** may include a random access memory (RAM) or another type of dynamic storage device that may store information and instructions for execution by processor **1120**. Memory **1130** may also be used to store temporary variables or other intermediate information during execution of instructions by processor **1320**.

ROM **1140** may include a ROM device and/or another type of static storage device that may store static information and instructions for processor **1120**. Storage device **1150** may

include a magnetic disk and/or optical disk and its corresponding drive for storing information and/or instructions. Storage device **1150** may include a single storage device or multiple storage devices, such as multiple storage devices operating in parallel. Moreover, storage device **1150** may reside locally on computer **100** and/or may be remote with respect to computer **100** and connected thereto via a network and/or another type of connection, such as a dedicated link or channel.

Input device **1160** may include any mechanism or combination of mechanisms that permit an operator to input information to computer **100**, such as a keyboard, a mouse, a touch sensitive display device, a microphone, a pen-based pointing device, and/or a biometric input device, such as a voice recognition device and/or a finger print scanning device. Output device **1170** may include any mechanism or combination of mechanisms that outputs information to the operator, including a display, a printer, a speaker, etc.

Communication interface **1180** may include any transceiver-like mechanism that enables computer **100** to communicate with other devices and/or systems, such as a client, a server, a license manager, a vendor, etc. For example, communication interface **1180** may include one or more interfaces, such as a first interface coupled to a network and/or a second interface coupled to a license manager. Alternatively, communication interface **1180** may include other mechanisms (e.g., a wireless interface) for communicating via a network, such as a wireless network. In one implementation, communication interface **1180** may include logic to send code to a destination device, such as a target device that can include general purpose hardware (e.g., a personal computer form factor), dedicated hardware (e.g., a digital signal processing (DSP) device adapted to execute a compiled version of a model or a part of a model), etc.

Computer **100** may perform certain functions in response to processor **1120** executing software instructions included in a computer-readable medium, such as memory **1130**. In alternative embodiments, hardwired circuitry may be used in place of or in combination with software instructions to implement features consistent with principles of the invention. Thus, implementations consistent with principles of the invention are not limited to any specific combination of hardware circuitry and software.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should instead be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A computer-implemented method comprising:

generating test configurations based on information regarding hardware or software, the test configurations directing at least one of setting up inputs for the test, measuring outputs for the test, or comparing the measured outputs with known criteria;

selecting a desired test configuration from the generated test configurations;

automatically generating, using a processor of the computer, test elements based on the desired test configuration, the test elements for testing at least one of the hardware or software, the generated test elements performing the testing by determining actions performed during the test;

generating a plurality of test vectors to test the hardware or software for the desired test configuration, the plurality of test vectors including one or more values for one or more parameters;

converting the desired test configuration to a script file, wherein the script file is written in an array-based language, a dynamically typed language, or any combination thereof;

automatically testing at least one of the hardware or software using the script file, wherein the testing includes:

performing, using a first set of one or more test vectors from the plurality of test vectors, a plurality of test iterations of one or more of the actions of one or more generated test elements, and

using at least a second set of one or more test vectors from the plurality of test vectors to determine the number of test iterations; and

producing a result based on the testing.

2. The computer-implemented method of claim **1**, wherein the desired test configuration reads data from and writes data to the hardware or software.

3. The computer-implemented method of claim **1**, wherein the hardware includes an instrument.

4. The computer-implemented method of claim **1**, wherein the hardware includes a device under test.

5. The computer-implemented method of claim **1**, wherein the software includes a data processing software.

6. The method of claim **1**, further comprising:

encapsulating the desired test configuration in a machine readable software library.

7. The method of claim **1**, further comprising:

generating a communication sequence for reading and writing data to the hardware or software, wherein the communication sequence selects the hardware or software to test, establishes a connection to the hardware or software, and applies the desired test configuration.

8. The method of claim **1**, further comprising:

exporting data acquired from testing the hardware or software.

9. The method of claim **1**, wherein the desired test configuration is automatically selected using the processor from the generated test configurations based on a predetermined criterion.

10. A method for testing comprising:

one of downloading software from the computer having the processor to another computer over a network or providing downloadable software from the computer having the processor to another computer over a network, which software when executed by the processor, causes the computer to perform operations comprising the method of claim **1**.

11. A computer-implemented method comprising:

generating test configurations based on information regarding hardware or software;

selecting a desired test configuration from the generated test configurations;

automatically generating, using a processor of the computer, test elements based on the desired test configuration, at least one of the test elements for performing actions on at least one of the hardware or software;

generating a plurality of test vectors to test the hardware or software for the desired test configuration, the plurality of test vectors including one or more values for one or more parameters;

converting the desired test configuration to a script file, wherein the script file is written in an array-based language, a dynamically typed language, or any combination thereof;

automatically testing at least one of the hardware or software using the script file, wherein the testing includes:

performing, using a first set of one or more test vectors from the plurality of test vectors, a plurality of test iterations of one or more of the actions of one or more generated test elements, and

using at least a second set of one or more test vectors from the plurality of test vectors to determine the number of test iterations; and

producing a result based on the testing.

12. The computer-implemented method of claim **11**, wherein the desired test configuration reads data from and writes data to the hardware or software.

13. The computer-implemented method of claim **11**, wherein the hardware includes an instrument.

14. The computer-implemented method of claim **11**, wherein the hardware includes a device under test.

15. The computer-implemented method of claim **11**, wherein the software includes a data processing software.

16. The method of claim **11**, further comprising:

encapsulating the desired test configuration in a machine readable software library.

17. The method of claim **11**, further comprising:

generating a communication sequence for reading and writing data to the hardware or software, wherein the communication sequence selects the hardware or software to test, establishes a connection to the hardware or software, and applies the desired test configuration.

18. The method of claim **11**, further comprising:

exporting data acquired from testing the hardware or software.

19. The method of claim **11**, wherein the desired test configuration is automatically selected using the processor from the generated test configurations based on a predetermined criterion.

20. A method for testing comprising:

one of downloading software from the computer having the processor to another computer over a network or providing downloadable software from the computer having the processor to another computer over a network, which software when executed by the processor, causes the computer to perform operations comprising the method of claim **11**.

21. A computer-implemented method comprising:

receiving a script file converted from a desired test configuration, wherein the script file is written in an array-based language, a dynamically typed language, or any combination thereof, and wherein the script file is converted from the desired test configuration by a processor that:

generates test configurations based on information regarding hardware or software, the test configurations directing at least one of setting up inputs for the test, measuring outputs for the test, or comparing the measured outputs with known criteria,

selects the desired test configuration from the generated test configurations,

automatically generates test elements based on the desired test configuration, the test elements for testing at least one of the hardware or software, the generated test elements determining actions performed during the test, and

generates a plurality of test vectors to test the hardware or software for the desired test configuration, the plurality of test vectors including one or more values for one or more parameters;

automatically testing at least one of the hardware or software using the script file, wherein the testing includes:

performing, using a first set of one or more test vectors from the plurality of test vectors, a plurality of test iterations of one or more of the actions of one or more generated test elements, and

using at least a second set of one or more test vectors from the plurality of test vectors to determine the number of test iterations; and

producing a result based on the testing.

22. The computer-implemented method of claim **21**, further comprising:

reading data from and writing data to the hardware or software.

23. The computer-implemented method of claim **21**, wherein the hardware includes an instrument.

24. The computer-implemented method of claim **21**, wherein the hardware includes a device under test.

25. The computer-implemented method of claim **21**, wherein the software includes a data processing software.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,819,493 B1
APPLICATION NO. : 13/692492
DATED : August 26, 2014
INVENTOR(S) : Gaudette et al.

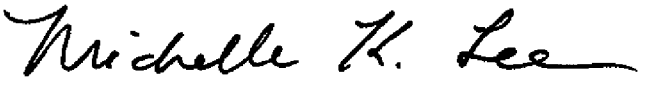
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

1. item (71) Applicant: "**The Mathworks, Inc.**, Natick, MA (US)" should be
--The MathWorks, Inc., Natick, MA (US)--.

2. item (72) Inventors: "**Michelle T. Hirsh**" should be **--Michelle T. Hirsch--**.

Signed and Sealed this
Twenty-third Day of December, 2014



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